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A Situation Report

THE KHAPRA BEETLE

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

THE KHAPRA BEETLE

THE WORLD'S WORST pest of stored grain and seeds--the khapra beetle--has invaded three southwestern States of the United States--Arizona, California, and New Mexico, and the State of Baja California, Mexico. Losses of stored barley and various seeds have ranged from 2 percent to total destruction. The beetle has a capacity for a prodigious rate of reproduction, and the surface of bulk-stored grain literally crawls with it during a heavy infestation. The insect apparently gained entry into California during World War II, but because of its similarity to the domestic black carpet beetle it was not brought to official attention until 1953. A Federal domestic quarantine was imposed on infested premises beginning in February 1955; State quarantines had been put into effect still earlier.

The khapra beetle spreads almost entirely by human agency. Traveling in grain or sacks, it would be possible for this insect to be distributed all over the United States. The infestation in the Southwest has so far occurred mostly in barley and in seeds such as grain sorghum, alfalfa, and Bermuda grass. But, should this destructive pest spread uncontrolled by the avenues possible in our transport system to the elevators of the Middle West, the damage would be incalculable. Its effect on the wheat industry alone could run into vast sums.

A program to control and eradicate the khapra beetle is in operation. Federal and State inspectors have found 225 infested premises in the three affected States. These premises are being gradually fumigated and released from quarantine. Meantime, inspectors are engaged in a constant search for other infested sites. Infested premises have been discovered, since June 1954, at the rate of 17 a month. A cooperative State and Federal research program is under way in Arizona and California, to learn everything possible about the beetle's behavior and control in this country. The Republic of Mexico and the State of Baja California are also cooperating in the effort to eradicate the insect from this continent.

DISCOVERY AND SURVEY

THE KHAPRA BEETLE has appeared repeatedly in past years at U.S. ports of entry and has been turned away as an undesirable immigrant. However, since the United States is a grain exporting rather than importing nation, the instances have been relatively few.

Although complete proof is lacking, indications are that the beetle slipped into the country in 1946 or earlier, during the stresses of World War II, in burlap, fish meal, or pistachio nuts from India and established itself in a California warehouse. There it was mistaken for the domestic carpet beetle, from which its larva can be differentiated only by an expert. In spite of control measures, the beetle increased so alarmingly that by 1949 some 300 tons of grain in the warehouse was a total loss. It apparently spread to other warehouses by way of burlap bags.

First published announcement of the presence of the pest in the Western Hemisphere appeared November 20, 1953--an unpretentious paragraph in the Agricultural Research Service's Cooperative Economic Insect Report of that date. The following month the insect was identified in Arizona.

In the early spring of 1954 the Standard Quarantine Committee of the Western Plant Board petitioned the Plant Pest Control Branch, Agricultural Research Service, for assistance in determining the distribution of the insect in the western States. A detection survey of grain-handling establishments in 10 States--Arizona, California, Colorado, Idaho, Nevada, New Mexico, Oregon, Texas, Utah, and Washington--was started early in April and completed in mid-June. The survey included all types of grain-storage and milling establishments, old mills and new, some that had been in operation 100 years or more, and some of the most modern flour mills in the West. But primary attention was directed to feed-mixing plants, which often have on hand commodities of such diverse origin as locally grown barley or wheat, cottonseed meal from Arizona or California, soybean meal from Minnesota, corn from Iowa, copra meal from the Philippines, and so on.

The source of these materials is important because of the return traffic in sacks. The destination of possibly infested materials was given careful consideration (one dealer whose warehouses contained khapra beetles had a shipping list that included firms in 30 States of the United States and 3 States in Mexico). Special attention was given to the distribution pattern of grain and seeds favored by the khapra beetle.

A major concern was shipment of materials from infested warehouses to points outside infested States. Shipping records of the past 2 years were examined and a record made of shipments likely to carry infestation. In cooperation with pest control officials in other States, inspections were made at points of destination. Railway cars carrying bulk grain were considered as a possibility of carrying infestation, and 400 cars used for this purpose are being traced and inspected.

As a result of this survey, it was learned that feed grains, barley and wheat for the most part, from Arizona and California have limited distribution to the north and east, occasionally moving into Colorado, Nevada, and Utah. Cottonseed meal and cake are supplied for the territory west of the Rockies almost without exception by firms in Arizona and California. Certified seed of sorghum, Bermuda grass, and alfalfa from these two States are prized throughout the West and move in considerable quantities throughout the country (California alone supplies more than half of the alfalfa seed produced in the United States).

Altogether, 492 warehouses and milling establishments were inspected in the 10-week survey, and infestation was found in 25 warehouses in 3 States (the beetle had been shipped from Arizona to New Mexico in sorghum seed). As a by-product, a heavy infestation of a closely related beetle was found in a mill in Washington.

The results of the survey were presented at the annual meeting of the Western Plant Board in June. The Board then requested the U. S. Department of Agriculture to (1) delimit the areas found to be infested, (2) engage in research work to determine the life history of the insect in this country, and (3) establish regulations to prevent its further spread.

The survey of premises has continued, by cooperating county, State, and Federal personnel. Following the initial survey and up to June 15, 1955, more than 4,500 properties were inspected in Arizona, California, Colorado, Louisiana, New Mexico, Oklahoma, Texas, and other States. Through July 30, 1955, 225 infested premises had been found--63 in Arizona, 158 in California (of which at least 45 make interstate shipments), and 4 in New Mexico.

THE INSECT

THE LIFE HISTORY of the khapra beetle (Trogoderma granarium Everts) has been described in several countries, and the literature shows certain variations in the insect's behavior from one place to another. When it turned up in the United States, there was a need to restudy it under our conditions. A regional research project on stored grain insects was enlarged to include work by the State of California at Riverside, the State of Arizona at Mesa and Tucson, and the U.S. Department of Agriculture at Fresno, Calif., and Mesa, Ariz. The results of research given below are mainly from the University of California, published March 1955, but the work is so intensive and the picture changes so rapidly--with research results often relayed by telephone ahead of the appearance of technical papers--that it represents by no means the last word to be said on the subject.

The insect is a native of India, Ceylon, and Malaya, where it is known as the most serious of all pests of stored grain. Its habit of congregating in cracks and crevices of bricks, masonry, and wood storage structures gives it the name khapra, a word in an East Indian dialect meaning "brick." Since the godowns or storehouses of India are commonly made of mud bricks, the insect comes naturally by its name of "brick beetle." The pest has been transported to and has become established in Africa, Asia, Australia, and Europe.

The female adult of the khapra beetle is a nondescript light- to dark-brown beetle measuring about one-eighth of an inch long, a little larger than a flea. The male is about one-third smaller. Adults are not believed to be able to fly, none having been seen in flight or captured in traps. The insect is not very mobile, walled portions of infested warehouses sometimes remaining free of it for months. The beetle depends upon man to spread it from place to place. Considering the large movement of grain, seeds, sacks, and other materials that might be infested by the khapra beetle, few countries have better facilities for its transport than the United States.

When adults emerge from pupae, they remain quiescent for a few hours to 10 days, depending on the temperature. Egg-laying begins soon after mating. If temperature and other conditions are very favorable, adults live only 3 days, but under adverse circumstances they may live as much as 47 days. This speed-up or delay in the life cycle extends through all stages of the insect's life history. Precisely contrary to the conditions we consider best for the human race--long life, low mortality, and high regard for the individual--in optimum situations for the khapra beetle the life span of the individual is shorter, more generations are produced per year, and the species flourishes rather than the individual.

The egg, measuring less than 1/64 inch in length, is generally laid singly rather than in clusters, scattered through the grain. The egg may hatch in 3 to 13 days, depending on the temperature. Viable egg production has ranged from 65 per female at 70° F. to 93 at 90° F. Extreme cold kills the egg, but a few survived a 2-hour exposure to a temperature as low as -5.8° F.

The yellowish-white newborn larvae are about 1/25 inch long. Normally they go through four stages (instars) of development, molting before each new stage. (But the number of molts may be as low as two in very favorable conditions and as high as 15 under extremely adverse conditions; in the latter case the larva becomes progressively smaller with each molt.) The mature larva, about 1/4 inch long, is a hairy yellowish worm with brown stripes across its back, giving a ringed appearance. As with many other insects, the larval is the destructive stage of the khapra beetle. Young larvae of the first three instars are unable to attack sound unbroken kernels of grain but they thrive on dockage until they reach the fourth instar and are able to eat large kernels. When mature larvae feed on this material, they leave many fragments and floury remains on which young larvae can feed.

Khapra larvae work mostly in the top 2 feet of grain in bulk storage, but they have been known to penetrate as deep as 9 feet. In large infestations larvae have been seen in this country to drop over the walls of a warehouse in such numbers that when vacuumed up at the end of a week they filled a 50-gallon drum. Inside another warehouse, in a like space of time, they have been taken up in such quantity that they filled a half-ton pickup truck. Scientists speak of "skyrocketing" and "explosive" development of populations of this insect, and of larvae "in uncounted millions." When the insects occur in great numbers they cause the grain to heat, owing to the life processes of many small bodies, sometimes building up the temperature from 70° to 104° F.

In California experiments, larvae lived from 19 days at the favorable temperature of 93° - 95° F. to 161 days at 70° F. Most of them survived a 28-day exposure to a temperature range of 24°-48°, some survived a 4-hour exposure to -5.8°, and they have been found to endure a 6-hour exposure to a high temperature of 120° F. These results seem to affirm that they could thrive or survive at any latitude in the United States, especially in heated warehouses. Furthermore, they now occur as far north as Great Britain and Korea.

Larvae kept at a 90° temperature have lived more than 5 months without food. Observers in other countries report that they can survive without eating for as much as 3 years. This poses a problem like few others in the insect world.

Among various foods tested for susceptibility to attack by the khapra beetle, wheat, barley, rice, and dried dog food seem to suit it best--as evidenced by the fact that

generations develop more quickly on these materials. The beetle also feeds upon the meats of almonds, pecans, and walnuts, spaghetti, egg noodles, pearl barley, tapioca, dried beans, flax, powdered beef blood, and powdered skim milk. When fed on dried fruits --peaches, prunes, and raisins--it seemed to use this as a diet for subsistence rather than development, no adults having been seen to appear.

The larva's habit of crawling into any kind of crevice to molt or pupate makes it a special problem. It burrows into sacking, weakening the material and causing it to tear. A favorite place of refuge is in the seams and ears of sacks, and the beetle has even been known to crawl into sacks containing insecticide. It takes refuge among the straws of brooms, in stocks of paper bags, even in sheets of insulation, and the hairy larvae can be carried on the clothing of warehouse workers.

The pupal stage has been demonstrated to last from 4 days at 93°-95° to as much as 19 days at 70°F. Pupae seem to endure cold less well than larvae.

In the California experiments, the life history of the khapra beetle, from egg to adult, has been found to range from 26 days--one generation in less than a month--at a temperature in the 90's to 193 days at 70° F.--a difference of nearly 800 percent in the length of a generation in a temperature range of only 25°. How far this flexible life history might stretch at lower temperatures remains to be seen.

WHAT IS BEING DONE

Quarantine

A PUBLIC HEARING to consider the advisability of a Federal quarantine on the khapra beetle was held at Denver, Colo., December 1, 1954. After taking testimony on the subject and thoroughly considering the situation, officials of the U.S. Department of Agriculture on February 21, 1955, issued a quarantine order for the States of Arizona, California, and New Mexico. The order prohibits the interstate shipment from infested premises of

- (a) all grains and grain products (including, but not limited to, barley, corn, oats, rye, and wheat) whether moved as such or in connection with other articles;
- (b) dried seeds and seed products of field and vegetable crops (including, but not limited to, alfalfa seed, cottonseed, cotton-seed meal and cake, flax seed, sorghum seed, soybean meal, pinto beans, and black-eyed peas);
- (c) bags and bagging (including, but not limited to, those made of burlap or cotton);
- (d) dried milk, dried blood, fish meal, and meat scraps; and
- (e) any other article which by reason of infestation or exposure constitutes a hazard of spreading the khapra beetle.

Interstate quarantine by the Federal Government is "conditioned upon the affected States providing for and enforcing control of the movement within such States of the regulated articles under the same conditions as those which apply to their interstate shipment." The affected States have quarantine regulations that prohibit the removal of any material that might spread the insect from property infested with the khapra beetle. Quarantines set up by neighboring States to prevent entry of infested materials have been withdrawn since institution of the Federal quarantine.

For the first time in the history of plant pest quarantines, infested premises rather than civil divisions of territory have been placed under quarantine. This is made possible because of the peculiar habits of the khapra beetle. It is not a field insect, but confines itself to indoor storage areas. It moves about very little of its own accord, and the quarantine is an apt device to prevent its movement by acts of men. The quarantine, in other words, is made to fit the case, and is in keeping with the Federal policy of

effectively controlling the pest while interfering as little as possible with the normal movement of trade.

After eradication of the beetle on any quarantined premise, the property is released from quarantine. Up to July 30, 1955, a total of 36 premises, 6 in Arizona and 30 in California, had been released from Federal quarantine after the necessary treatment.

Fumigation

Because of the insect's habit of crawling into cracks and crannies, control of the khapra beetle is a difficult insecticidal problem. Contact sprays do not reach it in all of these hideaways--warehouses thought to be clean after three or four sprayings have been refilled with grain and found later to have large infestations. The insect is not materially more resistant to insecticides than most other pests of stored grain. The difficulty is to deliver the insecticide to it.

Methyl bromide, a standard fumigation treatment of commodities under quarantine, has been found to be very effective for the khapra beetle. It has the added advantages of disposing of other grain pests as well and leaving no harmful residue in grains destined for human consumption.

Under laboratory conditions, it was determined that 2 pounds of methyl bromide per 1,000 cubic feet of area to be treated, applied for 4 hours at 80° F., was sufficient to kill exposed larvae in a gas-tight chamber. A large-scale test under warehouse conditions was carried out in California the week of January 3, 1955. The State of California, the Federal Government, the property owner, and the chemical and pest-control industries cooperated. The Agricultural Marketing Service, one of the Federal cooperators, was carrying out its mission, begun 30 years ago, to help rid commodities of damaging pests by means not harmful to commodity or consumer.

The warehouse chosen for the test measured 20 x 210 x 281 feet, had a mill tower 64 feet high, and contained more than a million cubic feet of space. The entire structure was covered with plastic tarpaulins, rolled and clamped at the seams to make them gas-tight, and anchored under 1 foot of earth around the base of the building. The surrounding area for a distance of about 100 feet was sprayed with malathion, an effective contact insecticide, raked the next day and sprayed again. The building contained 36,000 bags of sugar and about 100 bags of certified barley seed. More than 145,000 khapra beetles in all stages of development were placed in the building, some of them in remote corners. One lot of larvae was bolted between boards, three edges of which were sealed, so the gas could enter only from one end. Some were placed in sealed cloth bags. More than 5,000 pounds of methyl bromide was pumped into the sealed building, at the rate of 2 1/2 times the dosage required in laboratory tests. The gas was held in the building 48 hours, 12 times the laboratory requirement. Gas concentration was checked at 22 points in the building. After completion of the fumigation, cracks and crevices were intensively inspected, and test insects were removed and kept at a temperature of 93°-95° F. to see if any would revive. None did. The kill was 100 percent after 10 days and remained so at the time of a 30-day check.

On the strength of this and other tests, methyl bromide was authorized for the treatment of structures for eradication of the khapra beetle. Methyl bromide is a gas at ordinary temperatures, colorless and practically odorless, and dangerous to fumigation operators, who must wear gas masks when engaged in this work. When bulk grain is present in a building under fumigation, probe ducts and a blower system are needed to distribute the gas throughout the grain mass. The Federal Government officially disclaims liability in the event of injury to products or operators. Instructions are also given for the fumigation of commodities in freight cars or under tarpaulins. Commodities are released from quarantine on the basis of heat treatment used in their manufacture if a temperature of 180° F. is reached during any part of the processing, or if a temperature of 150° F. or higher is maintained for as much as 7 minutes during processing.

Great advances have been made in fumigation techniques for the treatment of entire buildings, and efforts are being made constantly to improve this program and reduce its cost. At least 2 1/2 times the laboratory dosage is still used as a safety factor in order to insure 100-percent kill in storage places. One warehouse yet to be fumigated has a capacity of 2.5 million cubic feet, and has elevators rising to 125 feet. "Tarping" such a building at the rate of about \$8 per thousand cubic feet and inserting more than 6 tons of methyl bromide is no inexpensive process. The various safety factors are maintained until proved not necessary to avoid repetition of an expensive process.

Means of reducing the actual amount of methyl bromide used without reducing the dosage have been discussed. One ingenious plan, not yet tried, would place a series of balloons in the warehouse being fumigated, each containing possibly 5,000 cubic feet of air. The balloons would displace a certain proportion of the space to be fumigated and hence reduce the amount of fumigant required.

Fumigation on a warehouse scale is still young, and many developments may be expected. Meantime the method is in operation, and is making life difficult for the khapra beetle as the insect is gassed in one warehouse after another.

Sanitation

Young larvae of the khapra beetle cannot attack whole kernels of grain but must survive on the crumbs. This fact invites consideration of grain sanitation as one method of control. Dirty grain and dockage are an encouragement to the khapra beetle, offering every inducement for it to thrive, to skyrocket in population, to do untold damage. Clean grain is a deterrent, useful against this and many other pests of stored grain.

Uninfested warehouses are cleaning up, for they are faced with the most serious threat to stored grain that has yet entered the country. A miller in Arizona told a Federal official that he used to pooh-pooh the idea of sanitation. Now he has five men engaged full-time at this work.

Grain sanitation, long urged by Federal and State authorities as a health and economic measure, is spreading because of the khapra threat. The benefits extend into other fields of pest control and will result in more wholesome handling of grain.

Identification

To eradicate the khapra beetle, it must first be found and recognized for what it is.

This is not always easy, for an initial infestation of the tiny organism, hidden in any convenient cranny, or the hairy larvae adhering to the pant legs of a warehouse worker may be difficult to detect. And, unless identified by an entomologist, it may be confused with the less damaging domestic carpet beetle.

To assist in the search, the Biological Sciences Branch, Agricultural Marketing Service, in January 1955 issued a 4-page folder, Have You Seen This in Your Grain? (PA-261), which describes and shows enlarged photographs of the insect in various stages, including the cast skins of larvae, which are valuable in identifying the beetle. It shows how to hand-sift and screen-sift grain for evidence of infestation, tells likely places to look for the insect, and explains how to mail specimens for identification. Copies are available from the Stored-Product Insects Section, AMS, U.S. Department of Agriculture, Washington 25, D. C.

Already there is widespread awareness of the problem. Specimens are sent to the Department of Agriculture from many States. Trained inspectors are searching through hundreds of warehouses, milling and feed establishments, trucks and railway cars, and other places where the khapra beetle might lurk. A long, hard, and painstaking job of work remains to be done.

Yet this ill wind has already blown some good. As a result of the campaign, officials have obtained more information than ever before on the occurrence and distribution of the domestic species of *Trogoderma*, which closely resembles the khapra beetle. Information also funnels in to State and Federal pest-control offices about other pests of stored grain. When the dust settles from the khapra campaign and there is time to assess this by-product information it may lead to steps against some other pests. "By the time the khapra beetle is eradicated," said one Federal worker, "a knowledge of the insect pests of stored grain will be firmly implanted in the minds of the people."

LOOKING AHEAD

A PROGRAM is in operation, with two simple aims:

1. Eradicate the beetle where it is found.
2. Prevent its spread to other places.

Fumigation, with the techniques and dosages worked out by research, is slowly realizing the first of these aims.

Quarantines, interstate and intrastate, seem to be realizing the second.

As one Federal official put it, "Our last thought is to live with the rascal."

The United States Government and the affected States are spending considerable sums of money to eradicate the khapra beetle. By July 1, 1955, California alone had expended or committed more than \$500,000.

But the program will take time. Up to about July 1, infested premises were still being found and quarantined faster than they were being fumigated and released from quarantine. A delaying factor in getting the big job of fumigation done--California had to fumigate 138 buildings with a total content of 32 million cubic feet--is finding concerns that can cover such large buildings with tarpaulins. Several firms combined to "tarp" the test building with a content of 1 million cubic feet. Another factor inhibiting quick extermination is the shortage of trained inspectors, who must be on the job throughout the 48-hour period of fumigation.

Against these delaying factors may be placed the always grateful fact that the khapra beetle travels almost nowhere under its own power. The two things that result in its spread by man--carelessness and lack of knowledge--are leaks in a dike that are being gradually plugged by the growing awareness of danger. With greater care and greater knowledge, movement of the khapra beetle can be stopped. Halted and confined, it can be eradicated. The finding of new infested properties and the release of others from quarantine may even now be in balance or gaining a little.

An entomologist of the Biological Sciences Branch said in March 1955: "The next 10 years should tell the tale of whether we can confine the khapra beetle to its present distribution, or whether it will spread throughout the United States. It has been the history of the khapra beetle that once established in a country it is difficult to eradicate. In fact, there is no record that it has ever been eradicated from a country in which it has obtained a foothold."

But, a Federal pest-control official says, "We face the job with optimism. We have the tools, and feel that there is a good possibility of eradicating the khapra beetle from the United States."

Information in this report was provided by the Biological Sciences Branch, Agricultural Marketing Service, and the Plant Pest Control Branch, Agricultural Research Service

